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Technology Selection Criteria and Methodology for Prioritizing Energy Research and Development Programs

by
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The U.S. Army Construction Engineering Research Laboratory (USACERL) has conducted an investigation into the development of an optimal strategy for selecting and prioritizing energy research and development (R&D) projects. This work is part of an ongoing effort to ensure that USACERL's R&D program includes an appropriate combination of new technologies for both short and longer term return on investment. The R&D goal is to provide the Army with the most effective equipment and processes for conserving energy.

Energy R&D work being conducted by various Governmental and private firms was reviewed and the methodologies for selection and prioritization of projects were analyzed. The processes require making judgments on key issues such as: probability of achieving performance goals; probable cost structures, commercial interest; status of competing technologies, and potential application of the technology. The existing approach taken at USACERL was compared with project selection methods of other Government and private organizations. Recommendations were developed for improving the selection criteria and methodology at USACERL.

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FOREWORD

This study was performed by the Energy Systems Division (ES), U.S. Army Construction Engineering Research Laboratory (USACERL), for the U.S. Army Engineering and Housing Support Center (USAEHSC). The work was completed under Project 4A162781AT45, "Energy and Energy Conservation"; Task A0, "Planning for Energy Efficiency"; Work Unit 016, "Energy Technology Forecasting." The USAEHSC Technical Monitor was B. Wasserman, CEHSC-FU-S.

The work was performed under contract by Arthur D. Little, Inc.; Dr. Peter Teagan and Lisa Frantzis are with A. D. Little. Larry Windingland was the USACERL Principal Investigator. Dr. G. R. Williamson is Chief of ES. The USACERL technical editor was Dana Finney, Information Management Office.

COL Carl O. Magnell is Commander and Director of USACERL, and Dr. L. R. Shaffer is Technical Director.

CONTENTS

FIGURES

TABLES

TECHNOLOGY SELECTION CRITERIA AND METHODOLOGY FOR PRIORITIZING ENERGY RESEARCH AND DEVELOPMENT PROGRAMS

1 INTRODUCTION

Background

The U.S. Army Construction Engineering Research Laboratory (USACERL) is conducting a long-range assessment, development, and demonstration program to evaluate emerging technologies such as energy modeling, heat recovery, renewable energy sources, energy management, conservation, controls, and fuel substitution.[1] These technologies have both short- and long- term potential for helping the Army achieve its energy goals as outlined in the Army Resources Management Plan.[2] However, the wide range of technologies and their varying states of development complicate the task of allocating limited financial and manpower resources to ensure continued success for the Army's far-reaching research, development, test, and evaluation (RDT&E) program.

Other Government and private organizations have devoted considerable attention to developing methods and criteria for selecting energy technologies and programming options for support. In doing so, they have addressed issues similar to those facing USACERL in terms of selecting an appropriate combination of technologies and timeframes to support productive research and development (R&D). In all cases, this process requires judgments to be made about a technology relative to:

- Probability of achieving performance goals
- Probable cost structures
- Market penetration, assuming cost-performance goals are met
- Commercial interest by manufacturers
- Status of competing technologies.

These and other factors enter into the process of "technology forecasting" to identify options showing the best potential of meeting the organizations' objectives.

The methods and criteria for technology selection at USACERL have unique characteristics determined by factors such as the laboratory's charter, energy use patterns within Army facilities, and special issues associated with Army applications (e.g., a captive market and different financial criteria). The overall thought process, however, is similar to that of other organizations with a large-scale RDT&E program for energy. Therefore, the experience of these other organizations could be very useful in USACERL's current effort to develop an aggressive RDT&E strategy for energy conservation and usage technologies.

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[1] L. M. Windingland, *Energy Technology Options and Their Status*, Draft Technical Report (U.S. Construction Engineering Research Laboratory [USA-CERL], May 1988).

[2] *Army Resources Management Plan, FY 86-95* (Headquarters, Department of the Army, January 1987).

Objective

The objective of this work is to assess project appraisal methods of other Government and private organizations and to recommend improved R&D project selection criteria and methods for USACERL. The goal is to enhance USACERL's energy research program to ensure an optimal response to the Army's current and future needs.

Approach

This work involves developing a set of criteria and methodologies which are appropriate to Army needs and conditions. The selection criteria and methodology must ensure that USACERL is consistent and systematic in addressing technology issues appropriate to the Army's needs and conditions. To develop the criteria, USACERL interviewed RDT&E managers at organizations having extensive near- and far-term programs. These managers represented both the Government (e.g., the Department of Energy [DOE]) and private industry (e.g., the Gas Research Institute [GRI]). The criteria used at these organizations were analyzed for applicability to the Army. Among the criteria considered were:

1. Current or probable commercial availability in the civilian sector.

2. Number of potential applications in Army facilities and associated energy use impacts (if widely used).

3. Economic performance as measured by parameters such as payback period and return on investment.

4. Skill level requirements of O&M personnel.

5. Strategic impacts as measured by parameters such as fuel flexibility and self-contained operation.

6. Environmental impacts (e.g., improved air quality, improved comfort conditions).

7. Special features requiring additional R&D to meet the Army's needs.

In developing the evaluation methodology, methods used by these other organizations were reviewed. Features potentially applicable to the Army needs were assessed for possible inclusion in USACERL's program. Recommendations were developed based on the findings.

Mode of Technology Transfer

The information resulting from this work will be reviewed by the U.S. Army Corps of Engineers National Energy Team (CENET), laboratory principal investigators, team leaders, and upper management to refine and enhance the existing selection process. The eventual product will be a more comprehensive method to evaluate the USACERL RDT&E energy program to ensure that the technologies developed meet the Army's needs with the best possible R&D return on investment.

2 SELECTION STRATEGIES AT OTHER ORGANIZATIONS

Of the major organizations surveyed, three in particular appeared to have selection processes with potential application to USACERL. These organizations were DOE, GRI, and the Electric Power Research Institute (EPRI). This chapter summarizes their procedures.

Gas Research Institute

The GRI plans, manages, and develops financing for a cooperative R&D program in supply, transport, storage, and end use of gaseous fuels for the natural gas industry and its customers. Their total planned 1987 contract budget for R&D was $158 million, of which $86 million was targeted for end-use projects. The underlying objectives of GRI in selecting technologies for development are to:

- Maintain market share in areas currently served by gas through development of more attractive end-use equipment
- Expand the use of gas by developing new equipment that captures markets not currently served by gas to any great extent
- Create new summer loads to both increase gas sales and make better use of capital invested in transmission facilities.

To meet these objectives, the GRI program portfolio is currently emphasizing:

- Cogeneration technologies suitable for residential, commercial, and industrial applications
- Gas-fired heat pump technologies to maintain current heating markets and gain expansion into gas-cooling markets
- Improved appliances to maintain and possibly expand the market share
- "Smart House" technologies that provide flexibility for using gas in homes to serve a full range of heating, ventilating, and air-conditioning (HVAC), cooking, and air quality control functions.

GRI has a formal procedure called the "Project Appraisal Methodology (PAM)" for setting budget priorities (Figure 1). As part of this process, GRI reviews all technologies at four potential funding levels. Two senior-level GRI committees oversee the appraisal and budgeting process and assist in formulating an R&D strategy. The Senior Research Council (SRC), composed of vice-presidents from various divisions within GRI, meets three times per year to review each project area. The final output of these meetings is a list of candidate R&D activities and associated budgets for a 5-year R&D plan. GRI's Operating Committee then meets to review the literature and finalize outstanding issues. This committee consists of three vice-presidents from SRC, GRI's president, and several senior vice-presidents.

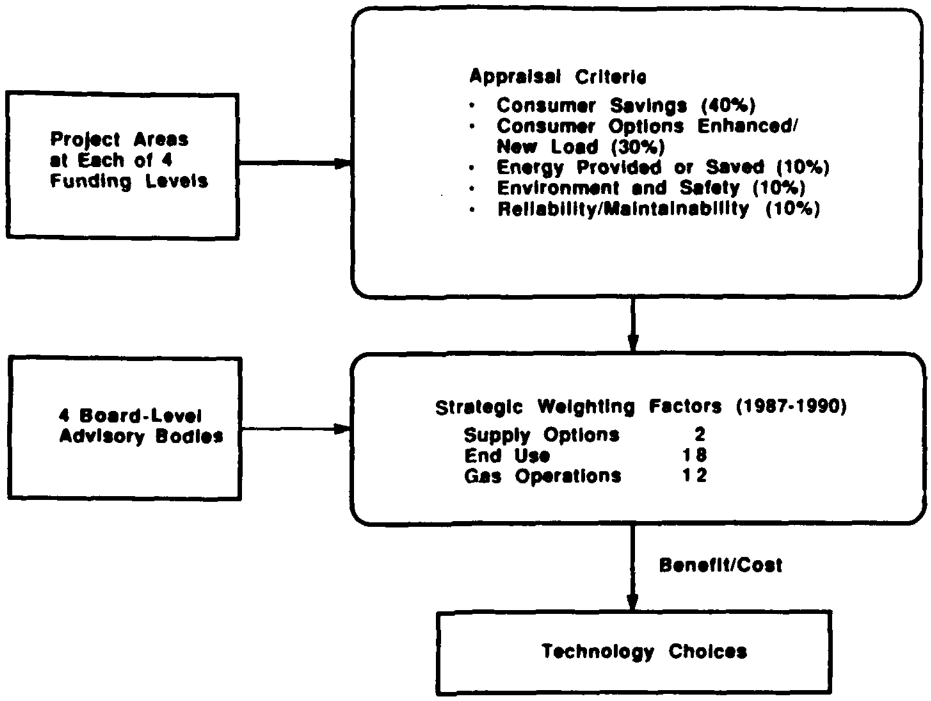

Figure 1. The Gas Research Institute's PAM process.

The preliminary list of technologies and associated budget levels generated from these two GRI committees must then be reviewed by four board-level advisory groups. These advisory groups consist of eminent individuals from outside and within the gas industry. When reviews by these groups are completed, GRI's Planning and Appraisal Department prepares an R&D plan and budget that are reviewed further and then submitted to the Federal Energy Regulatory Commission (FERC) for approval. GRI has used PAM to target the following end-use technologies for development during 1987-91:

- Cost-competitive heaters for room comfort control
- Cost-competitive gas appliances
- Technologies to expand use of gas for cooling and dehumidification
- Gas engine and fuel cell cogeneration
- Cost-effective burners, controls, and energy recovery
- Gas-fueled process equipment
- Gas heat pump
- Compressed natural gas for vehicle fuel
- More end-use material and equipment based on improved understanding of combustion and methane conversion.

Department of Energy

The two DOE divisions conducting R&D on technologies of interest to USACERL are (1) Fossil Energy and (2) Conservation and Renewables, which are highlighted in the DOE organizational chart shown in Figure 2. The mission of Fossil Energy is to promote high-efficiency systems that will reduce dependence on imported fuels and minimize pollutants entering the environment. This division is heavily influenced by industry and Congress. Approximately 90 percent of its activities focus on clean coal technologies. The priority funding areas in Fossil Energy R&D, which has a budget of $275 million and $400 million for a Clean Coal Demonstration Program, are acid rain technologies, combustion, and flue gas clean-up. Oil and gas programs currently receive only about 10 percent of these funds, with coal receiving about 85 to 90 percent. Several billion dollars are also expected to be appropriated for the Clean Coal Program in the near future.

Conservation and Renewable Energy's mission is to promote new technologies to broaden the list of options available to industry. This division collaborates a great deal with industry and provides a major support base for embryonic technologies. The appropriation for Renewable Energy in FY87 was $170 million; Energy Conservation received $430 million.

The technology selection process involves peer reviews with participants consisting of representatives from industry and organizations such as the National Academy of Science, GRI, and EPRI who will make recommendations to DOE about technology program efforts. Contractor reviews (university groups, laboratories, consultants) are also conducted on a regular basis to identify and exchange information on new technologies and breakthroughs. Strategic planners and the Energy Research Advisory Board (ERAB) within DOE then assess the various stages of different technologies based on research and the contractor and peer reviews. ERAB has 30 members, mainly from the executive vice-president and chief executive officer (CEO) level. The Board's basis for choosing technologies is primarily a judgment call, with no quantifiable methodology. The factors they consider are:

- Current developmental state of the technology
- Payoff in terms of potential energy to be saved
- Whether DOE research will significantly advance the technology
- Whether industry lacks the capital to develop the technology
- The degree of technical risk--
  - DOE is in a better position than industry to take on initial research with technologies that have a high technical risk but potentially good payoff
  - Technologies with longer payoff times are better suited for initial R&D at DOE than in the industrial sector
- How well the technology will support the goals of the National Energy Policy Plan
- How much it will cost to advance the technology to a usable state
- Environmental acceptability of the technology

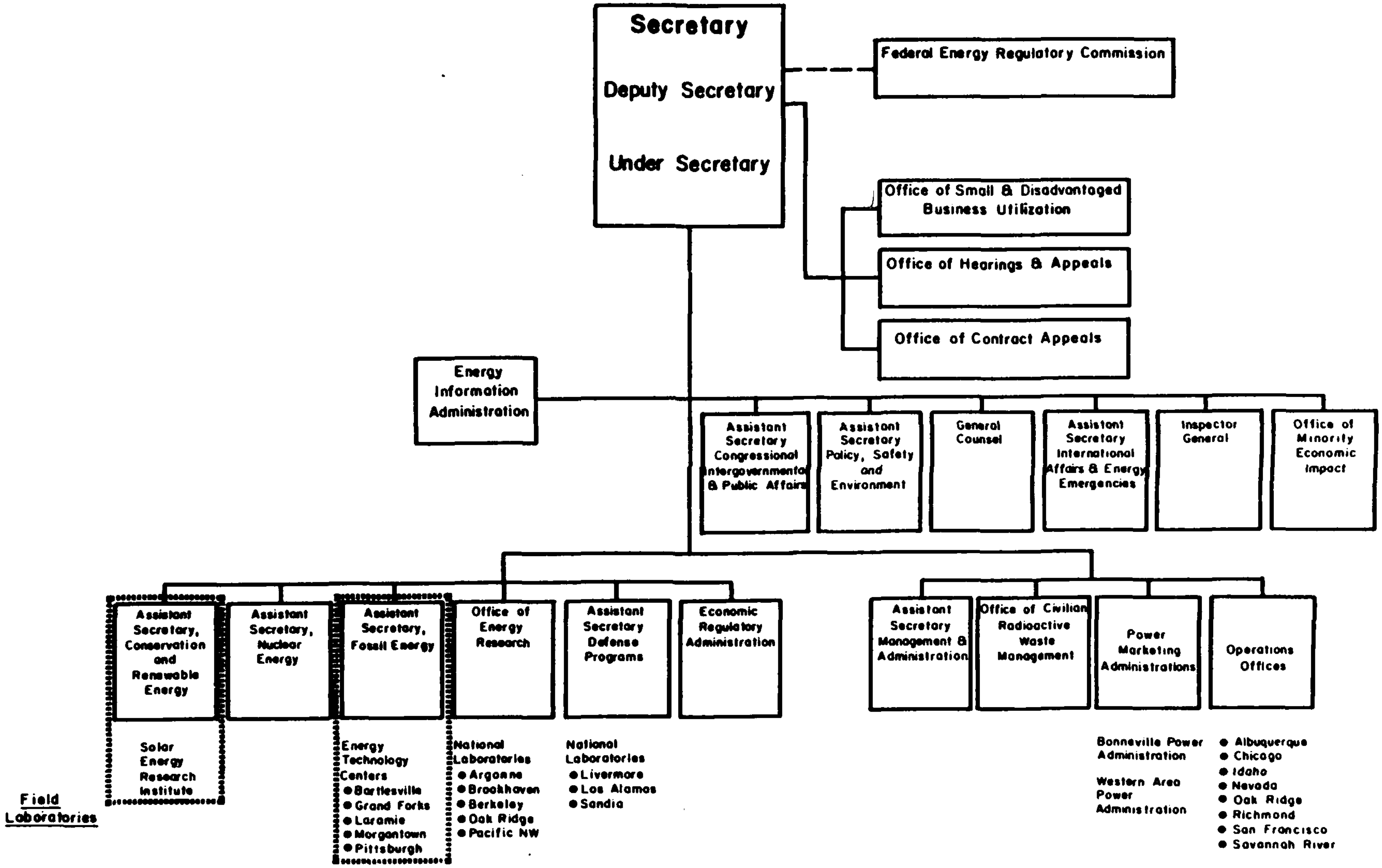

Figure 2. Department of Energy organizational structure.

- Market penetration potential

- The outlook for industry to cost share and eventually take over development of the technology.

DOE makes recommendations to the Office of Management and Budget (OMB) which has fiscal constraints that limit even further the dollar funding and choices for technologies to be developed. Congress, with input from influential industry lobbies, defines the ultimate budget and technology directions for DOE.

Electric Power Research Institute

EPRI's mission is to lead and perform R&D to help the electrical utility industry furnish highest value energy services through:

- Improved equipment to increase and/or maintain market share

- Technologies that will reduce peak demands on utility companies, especially during summer.

The 1987 budget for EPRI's R&D activities totaled $239 million, of which $23.1 million was for utilization and $163.3 million for generation. The major emphasis is currently efficiency and load management given the goals of least-cost planning and demand-side management at many utilities. EPRI has five inputs into its planning document: the Project Advisory Committee; member utility committees; the Advisory Council; EPRI staff; and the EPRI Board of Directors. These groups seek to guide EPRI research in a way that will add value to the electric utility industry.

Strategic planning at EPRI includes information gathering, analysis, and formulation of broad statements of direction and emphasis. These statements are summarized biannually in a publication titled *Electricity Outlook: A Foundation for EPRI R&D Planning*. Questions guiding the planning process include:

- What is the problem or opportunity faced by the utility industry?

- Is R&D needed to provide the information or technology to solve the problem or take advantage of the opportunity?

To address these questions, member utility executives are surveyed biannually. Specially designed workshops that focus on important topics and their R&D implications are held regularly by the EPRI Board of Directors and the Research Advisory Committee (RAC). All RAC members are utility executives with 3-year terms.

For 4 months at the beginning of each year, EPRI staff and the industry committee (structure shown in Figure 3) review strategic considerations and establish key areas for EPRI R&D activities. After EPRI senior staff review the program directions relative to the previous year's plan, the Board of Directors sets the expenditure level. Within 7 months, recommendations for the allocation of resources to the highest priority areas are made to the RAC. The RAC must also receive input from designated EPRI staff and committees in order to reconcile priorities for the entire EPRI program. Utility members have direct input as shown in Figure 3; their responsibilities are outlined in Table 1.

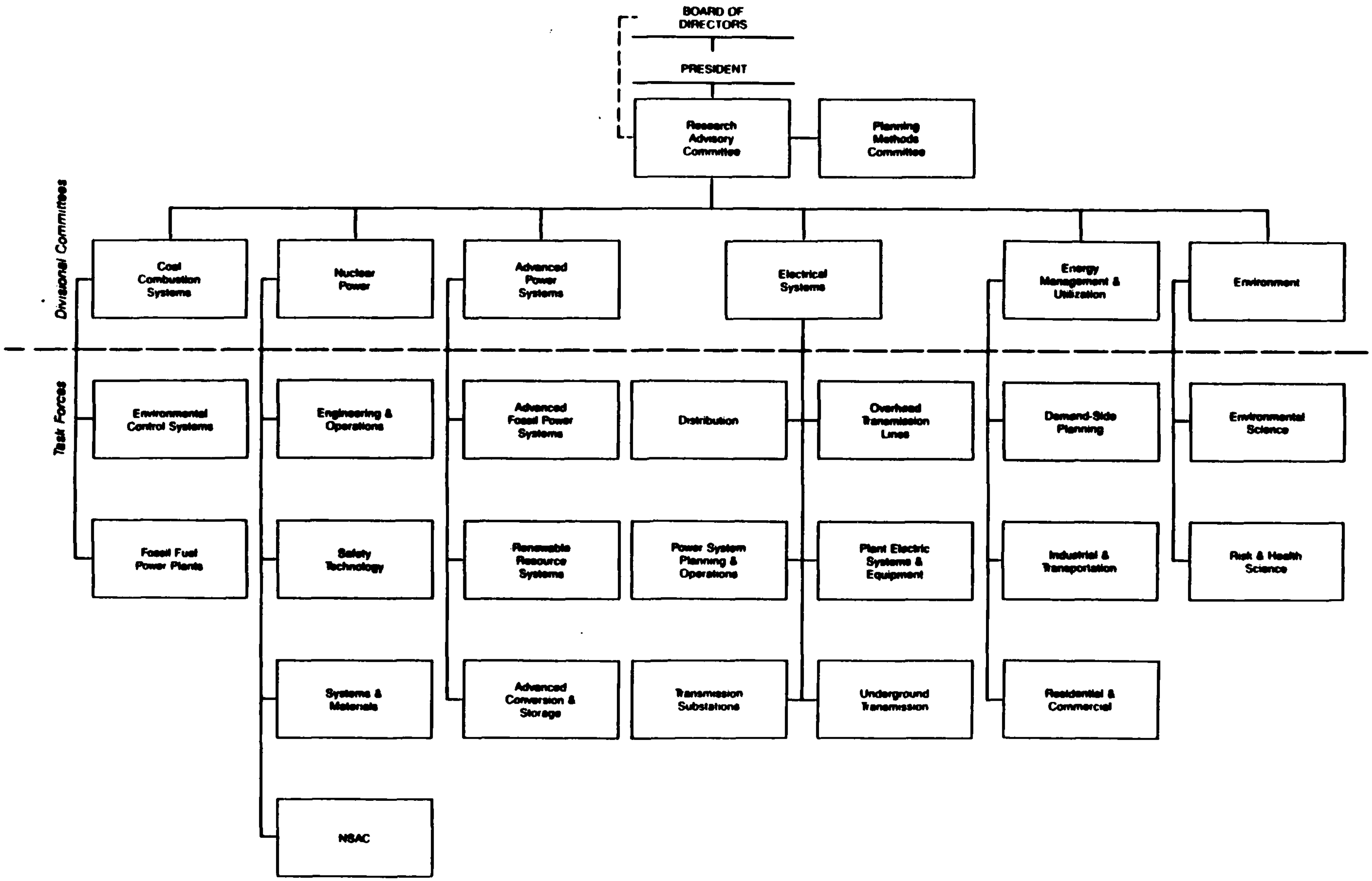

Figure 3. EPRI Industry Committee structure.

Table 1

Policy and Procedures Governing EPRI Industry Advisory Group Participation in Project Review, Program Planning, and Technology Transfer

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A. Major responsibilities of the Research Advisory Committee are:

(1) Identifying broad industry R&D needs;
(2) Achieving and maintaining balance and appropriate emphasis among EPRI divisions in EPRI R&D plans;
(3) Considering issues involving technical policy;
(4) Reviewing proposed large projects;
(5) Assisting in the identification and review of EPRI R&D accomplishments;
(6) Managing the organization and operation of the EPRI Industry Committee Structure; and
(7) Directing and implementing processes for the transfer of EPRI-developed technology.

B. Major responsibilities of divisional committees are:

(1) Identifying R&D needs in their areas of concern;
(2) Reviewing the R&D plans for their respective divisions, giving appropriate balance to planning inputs, and advising on relative emphasis within divisional plans;
(3) Considering issues involving technical policy;
(4) Reporting to the Research Advisory Committee on progress and results at the division and program levels;
(5) Assisting in the identification and review of EPRI R&D accomplishments; and
(6) Assuming an active role in the transfer of EPRI R&D technology.

C. Major responsibilities of task forces are:

(1) Identifying specific R&D needs as inputs to EPRI R&D plans;
(2) Reviewing the R&D plans for their respective programs;
(3) Reviewing and advising on proposed projects and requests for project approval (RPAs);
(4) Reporting to the divisional committees on progress and results at the program, subprogram, and project levels;
(5) Assisting in the identification and review of EPRI R&D accomplishments; and
(6) Assuming an active role in the transfer of EPRI technology.

Industry advisory committees review the draft program plan after the RAC, utility, and staff comments have been incorporated. The final R&D strategy and budget are decided by the EPRI Board of Directors. The Board has approximately 35 members who are primarily CEOs of EPRI member utilities. Once the final plan has been approved, the Planning and Evaluation Division within EPRI is responsible for coordinating output from all of the planning activities. The *EPRI Research and Development Program Plan* is published annually to announce the outcome of this process.

Project implementation is initiated when program committees, advisory task forces, and the technical division's vice-president review staff Requests for Project Action (RPAs). The factors considered in their review are:

- Consistency with EPRI plan, goals, and objectives
- Availability of funds
- Coordination of similar work in progress or planned
- Probability of technical and commercial success
- Reliability of cost estimates
- Available cost sharing by contractors or other participants
- Schedule
- Potential contractual problems, legal restrictions, or policy considerations.

This planning/implementation process has worked successfully for EPRI over several years by providing valuable input from within EPRI, member utility companies, industry, and the Government. These groups have helped to define the current primary objectives at EPRI, which were mentioned earlier.

3 USACERL CHARTER AND CURRENT STRATEGY

In developing technology selection criteria applicable to USACERL, it is necessary to understand the Laboratory's charter and current strategy. This background will enable a comparison between USACERL's strategy and those of the organizations discussed in Chapter 2 to determine if USACERL's R&D planning process can benefit from incorporating features of the others.

Charter

USACERL is chartered as the Army's lead laboratory for construction engineering research in support of Army-operated facilities. One of the four USACERL Divisions is devoted to R&D for introducing new and/or improved energy technologies. An additional function of this Division is to provide guidance and support to Army facilities worldwide in implementing energy usage concepts and equipment--particularly where the technology is unfamiliar to facility engineers. Special emphasis is given to new and developing energy-related technologies that could substantially improve Army operations in the future.

In pursuit of the above objectives, USACERL undertakes a wide range of R&D activities. The nature of the USACERL program initiatives depends on the status of the technology to be investigated. For purposes of this discussion, these initiatives are divided into three categories:

1. Experimental technologies--currently under development and several (5+) years away from commercial availability.

2. Developmental technologies--not yet commercially available, but in an advanced stage of development and possibly available shortly for use in Army facilities.

3. Recently commercialized technologies--available on commercial markets, but with only limited field experience (particularly at Army facilities).

The program initiatives shown in Figure 4 assume that, once a technology is well established and widely accepted by the engineering community, USACERL's role becomes minimal since site engineers, vendors, and engineering consulting firms can provide the follow-on development needed to commercialize the product. USACERL's primary level of effort is focused at the precommercial stage of development.

Current R&D Strategy

USACERL's R&D program involves technologies in all three categories. The overall strategy in meeting its R&D objectives can be summarized as follows:

- Application assessments--evaluating the technical/economic performance in candidate Army applications and estimating the impacts of widespread implementation.

- Field demonstrations--supporting the installation of systems in applications having a high potential for success and disseminating the field test results to Army decision-makers.

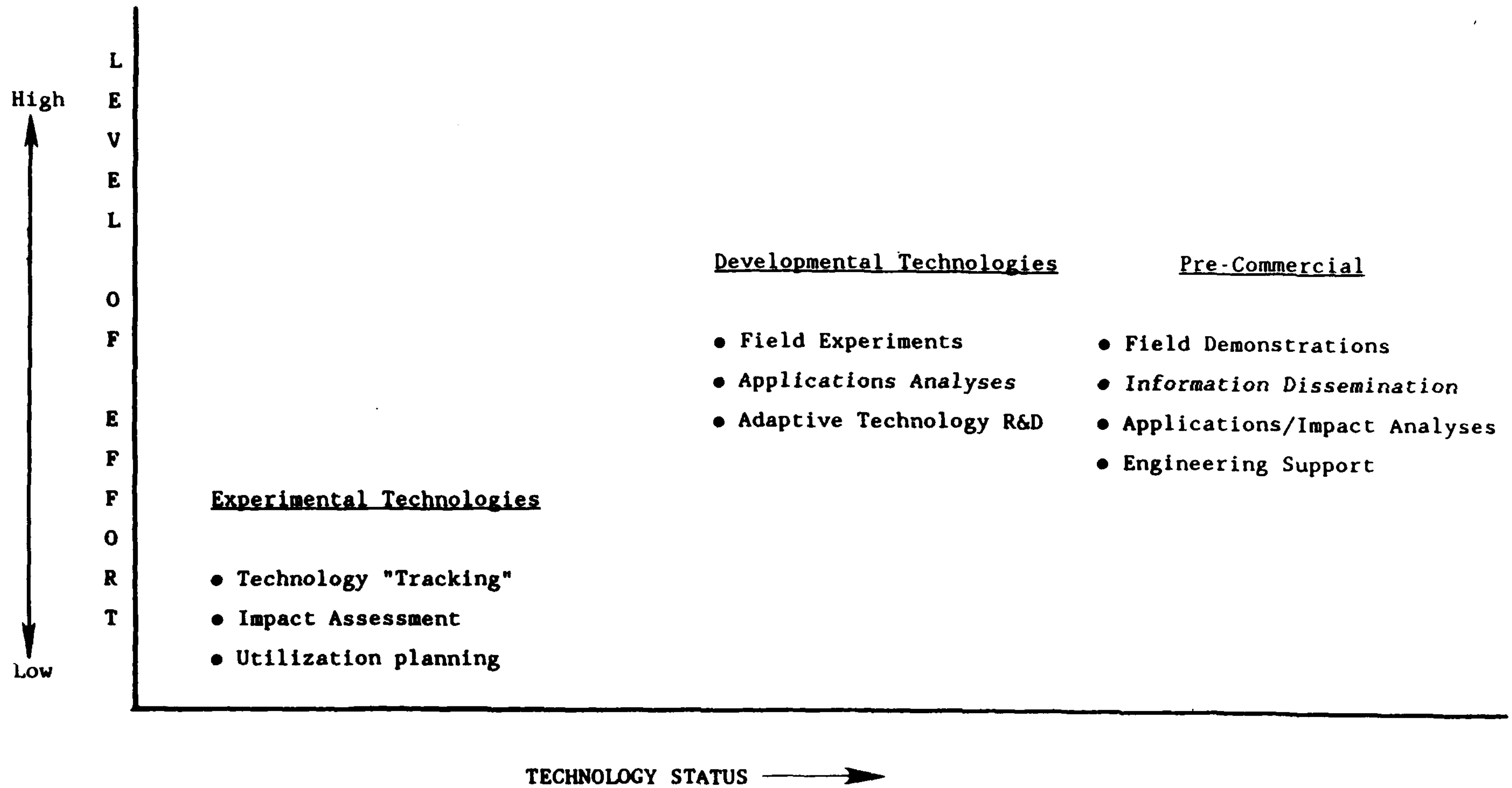

Figure 4. USACERL support/role in technology development.

- Equipment modification--
  - Identifying possible modifications to equipment that would make it better suited for Army use. Such modifications could include changes in capacity, O&M procedures, and packaging.
  - Conducting field experiments with the modified technology to verify performance.

The percentage of the USACERL program devoted to technologies in each of the three developmental stages is determined by several factors. Among the considerations are: the area impacted (i.e., mission criticality and extent of application); the predicted time lapse before the technology will actually be usable; the projected return on investment; availability of potential technology transfer mechanisms; and many other factors. The thrust of USACERL's involvement with each developmental stage is outlined below.

Experimental Technologies

Industry and developmental organizations support a number of advanced energy technologies that could impact Army applications in the longer term. These technologies include high-frequency ballast lighting, Stirling-engine-driven heat pumps, coal-fired diesel engines, multijunction photovoltaics, solid oxide and carbonate fuel cells, thermochromic glazing materials, and smart house/building concepts.

These technologies are characterized as being in an R&D stage with limited operational experience. The role of USACERL relative to these technologies is to "track" their progress and assess their potential impact on Army operations. The pragmatic implications are to:

- Keep abreast of technology developments and their anticipated commercial availability
- Assess the impact of the technologies on Army operations should R&D be successful
- Develop potential field experiments and technology adaptation program plans for implementation once the technology advances to the developmental stage.

Developmental Technologies

These technologies are advanced but not yet economically feasible in most applications; they could, however, have major impacts in a 5- to 10-year timeframe due to projected technical improvements or changing energy economics. Technologies in this category include advanced photovoltaics, fluidized bed combustion, internal combustion engine-driven heat pumps, and advanced batteries. USACERL strives to maintain up-to-date information on these technologies with an assessment of their potential for impacting Army operations. USACERL can support widespread use of such a technology in Army facilities when it becomes economically attractive. This programmatic approach includes:

- Application assessments--evaluating the economic and energy use impacts of the technology as applied to Army facilities, assuming technology cost/performance goals are achieved.

- Field experiments--pilot testing the technology in the field to gain operational experience as a sound basis for future planning activities.

Precommercial Technologies

At any point in time, there is a class of technologies that is fairly well defined technically, but still not widely used in practice. Examples of technologies at this stage are variable-speed-drive heat pumps, packaged cogeneration units, direct digital control, and condensing heat exchangers. In many cases, there are limited commercial sales of equipment or the technology is still being field-tested by the developmental organization. Many of these products could have widespread application at Army bases. USACERL's role for this class of technologies is to:

- Advise Army facility engineers on how it can be applied effectively

- Perform an Army field demonstration of the technology

- Provide data on application of the product (preferably related to Army facilities), including technical performance, vendor reliability, operation and maintenance (O&M) requirements, and cost (i.e., verify performance).

4 DIFFERENCES BETWEEN ARMY AND CIVILIAN APPLICATIONS

As discussed earlier, the differences between Army and civilian energy applications must be understood before defining an appropriate planning process for USACERL. This chapter discusses some differences that may affect the USACERL criteria and their degree of importance. Of particular significance are six basic areas: economic criteria; onsite O&M staff; concentrated market; political influences/national goals; district heating/onsite power; and operational control/demand management. These areas are examined below.

Economic Criteria

The Army will generally accept a longer payback period than the civilian sector. For example, the required payback period for commercial applications is about 2 to 3 years (maximum) whereas the Army accepts 3 to 6 years as economically attractive. Thus, some technologies might hold interest for the Army while having only modest market potential in civilian applications. Examples of these technologies include packaged cogeneration, solar water heating, desiccant dehumidification, gas-fired heat pumps and some forms of heat recovery.

Onsite O&M Staff

Most Army facilities have a trained O&M staff that performs routine maintenance on a wide range of electrical and mechanical equipment. This situation is in contrast to the civilian sector where most commercial and residential facilities do not have in-house maintenance staff. As a result, in the civilian sector, even routine maintenance procedures such as periodic oil changes require costly site visits by outside O&M personnel. For example, it is estimated that a service call costs between $50 and $80, excluding actual work done onsite.

The Army's onsite O&M staff might improve the feasibility of several important technologies that require periodic routine maintenance when compared with the situation in the private sector. Examples of technologies that could benefit from onsite O&M staff are gas-fired cooling systems, packaged cogeneration, and evaporative coolers.

Concentrated Market

Marketing and servicing equipment in a diffuse market (typical during early introduction of new technologies) are costly and detract from the equipment's economic benefit. However, Army facilities provide a concentrated market that can reduce installation and maintenance costs. For example, installing a number of ground-coupled heat pumps in close proximity to one another can significantly reduce installation costs since trenching equipment can be used efficiently. Similarly, O&M costs are reduced when multiple units are installed over a relatively compact area since travel time is minimized.

The potential for having multiple systems installed in a single Army facility, therefore, could greatly improve the economics of several technologies compared with the private sector outlook. Examples include ground-coupled heat pumps, engine-driven air-conditioning, packaged cogeneration, and wind energy systems.

Political Influences/National Goals

The Government has an evolving strategy relative to energy use and development which, broadly stated, includes:

- Reducing (or limiting growth in) the use of premium fuels and associated need to import fuels
- Increasing use of indigenous energy resources--most importantly coal
- Increasing use of renewables.

Government facilities, including those operated by the Department of Defense, are expected to be at the forefront of implementing overall national goals in this field. Thus, the Army is often directed to implement new energy technologies before they are widely accepted in the civilian sector.

District Heating/Onsite Power

The use of district heating/onsite power systems is declining in the United States. Reasons for this trend include the complex institutional problems associated with "right of ways" for piping systems, difficulty in maintaining piping systems placed under public ways (city streets), utility interface problems--particularly when power must be transferred across property lines--and ensuring adequate long-term loads where multiple customers are involved. However, Army facilities are under central control and can avoid all or most of these institutional problems. Consequently, Army bases could be particularly good candidates for expanding the use of district heating/onsite power systems using both conventional system approaches (heat distribution via pipe lines) and novel system approaches based on distributed heat pumps.

Technologies that could contribute to expanded use of district heating/onsite power include:

- Modular power generation technologies that use coal and other solid fuel forms (e.g., fluidized bed combustion)
- Load management technologies to make more efficient use of central energy sources (e.g., better matches between electric and thermal loads, reduced capacity requirements)
- Heat pump systems (air source and ground-coupled) to serve heating and air-conditioning loads in scattered buildings
- Modern piping and trenching systems.

Operational Control/Demand Management

Many of the larger Army bases are similar to small towns, having a mix of residential, recreational, and commercial facilities. In the civilian sector, all buildings are metered and owned individually so that strategies for load management are developed for each building. Army bases, in contrast, buy bulk power and handle internal distribution. Increasingly, the cost of utility-supplied electrical power is associated with demand charges. At some Army facilities, these charges already constitute about 50 percent of the total electric bill and this percentage will probably grow over coming years.

The Army is in a unique position to develop wide-scale strategies for controlling electrical energy and demand costs. These technologies include load management, energy storage, and the use of gas-fired air-conditioning/refrigeration. There are major benefits to be gained from employing similar strategies where district heating and/or centralized onsite power systems are used, since capacity requirements would be reduced, resulting in more efficient use of capital equipment (improved capacity factors, etc.).

5 A PROPOSED R&D PROGRAM PLANNING PROCESS

The R&D program planning processes of GRI, EPRI, and DOE discussed in Chapter 2 were evaluated for potential application at USACERL. This chapter highlights the methodologies and thought processes that could be incorporated into an overall USACERL criteria set and technology selection process for energy R&D.

In summarizing the R&D planning processes of the organizations in Chapter 2, most use a process similar to that depicted in Figure 5 to identify technologies with the greatest potential for meeting their program goals. The basic question being addressed is which technologies can make a difference as measured by parameters such as decreased use of fossil fuels (DOE), increased use of natural gas in the summer (GRI), or greater penetration of electrical heating (EPRI). Details of these questions and criteria differ by supporting organization; however, the thought process for arriving at the solution is very similar for all of the organizations. It appears that a similar process could apply to USACERL's planning program. The questions that would be addressed by the process include:

- What energy technologies could significantly impact energy use in existing facilities which will be of paramount importance over the near term? What quantitative impact would these technologies have for different implementation rates?

- Which energy technologies might be implemented in new facilities and how would these facilities be designed to best utilize advanced technologies? What would be the quantitative impact of these new construction technologies given the relatively low new/replacement building program (about 2 percent per year)?

- What technologies can best be used to reduce electric demand charges which increasingly contribute to high electricity costs?

- Which energy technologies will be most important in allowing the Army to switch to more plentiful domestic energy resources (coal, renewables, etc.) consistent with national policy? How big an impact could a realistic fuel switching program have and what would be the capital cost requirements of such a program?

Currently, USACERL energy technology programs tend to be developed on a project-by-project basis with only limited analysis of the impacts of implementing the technology on a widespread basis. This procedure makes it difficult to assess which technologies should receive priority and is the single major difference between the USACERL process and those of the major technology development organizations, such as DOE. USACERL could benefit from an approach to better identify technologies that could have major impact on energy use patterns. After analyzing the approaches used by other R&D organizations in terms of the Army's unique situation, a process can be proposed for USACERL. The details are given below.

Proposed Process Outline

As indicated in Figure 5, the proposed process entails three steps leading to a development plan that prioritizes technology thrusts based on the near- and long-term potential to meet energy savings and strategic goals.

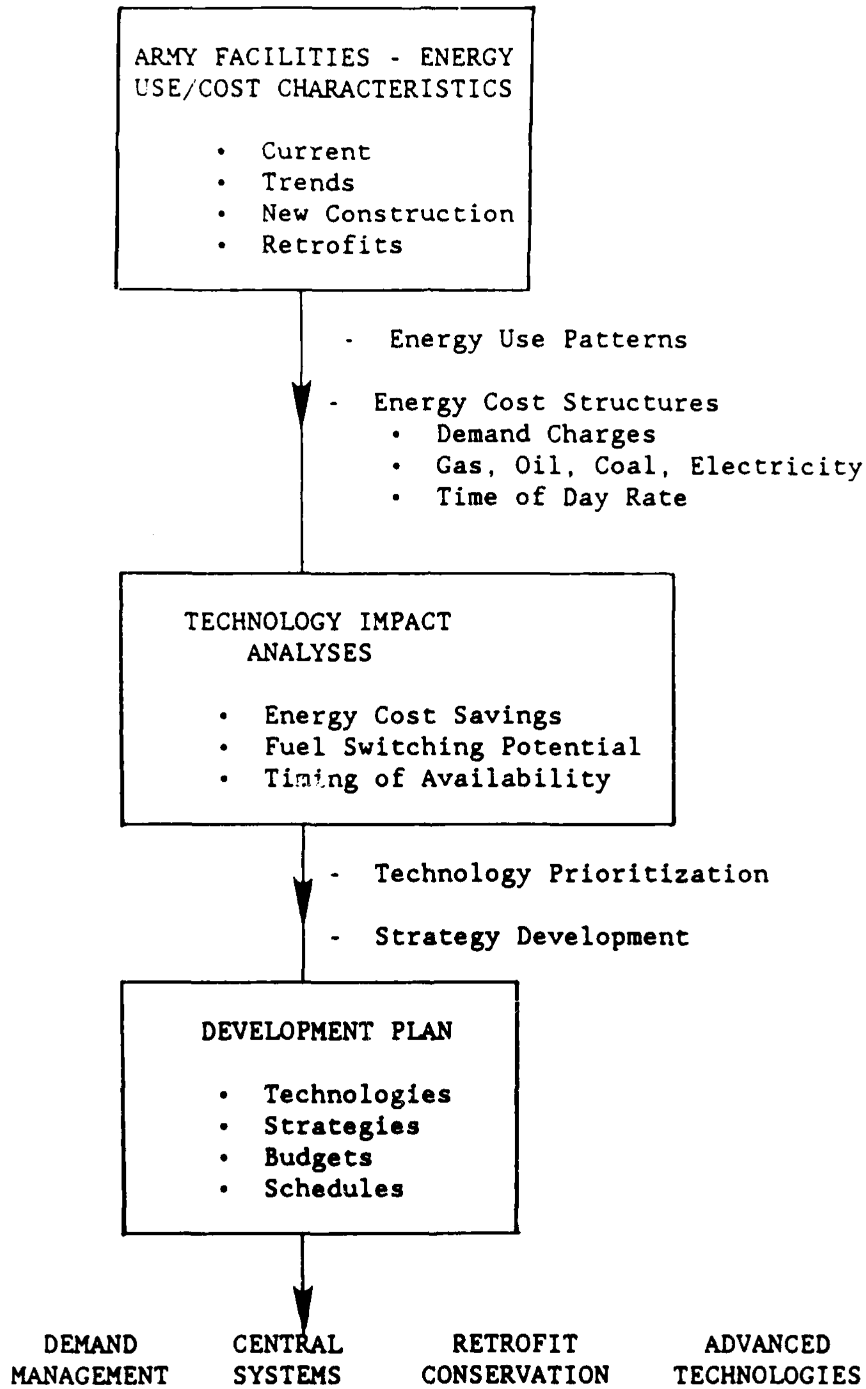

Figure 5. Proposed R&D program planning process.

Step 1: Define Energy Use Patterns

This step requires an analysis to define energy usage and cost patterns in Army facilities. The information generated would include:

- Energy use by building/facility type
- Energy use by application (i.e., lighting, air-conditioning, hot-water heating)
- Electricity cost trends and how they are being impacted by increasing demand charges and changes in the load characteristics (e.g., the increasing use of air-conditioning)
- Characteristics of equipment currently being used to perform energy delivery and usage functions
- Energy use intensity and seasonal variations (required to assess the potential for district heating technologies).
- New building plans and the associated increase in energy demand over current levels.

Step 2: Analyze Technology Impact

The information from step 1 would be used to assess the impact in both the near and longer term of energy supply and end-use technologies being considered for use at Army facilities. The types of analyses that would be done as part of the assessment process would include:

- Estimating the technical performance characteristics of the technology as used in typical Army applications. As an example, this information would often take the form of annual energy savings per installed kilowatt of capacity.
- Estimating the economic performance of the technology based on both near-term cost structures and those projected for the longer term. Economic performance parameters that might be used include simple payback period and return on investment. Figure 6 shows the form this economic performance information might take to allow for assessing both near- and long-term potential.
- Estimating the system-wide energy use and cost savings potential resulting from a range of implementation rates. Figure 7 is one form such information might take for two generically different technology classes.
- Estimating the capital cost requirements of implementing a program that involves widespread use of the more attractive technology options as measured by favorable economic potential and large impacts projected if implemented successfully.

The above process would help R&D managers identify technologies showing the most promise of being implemented economically at Army bases and of making major contributions to energy savings and strategic goals.

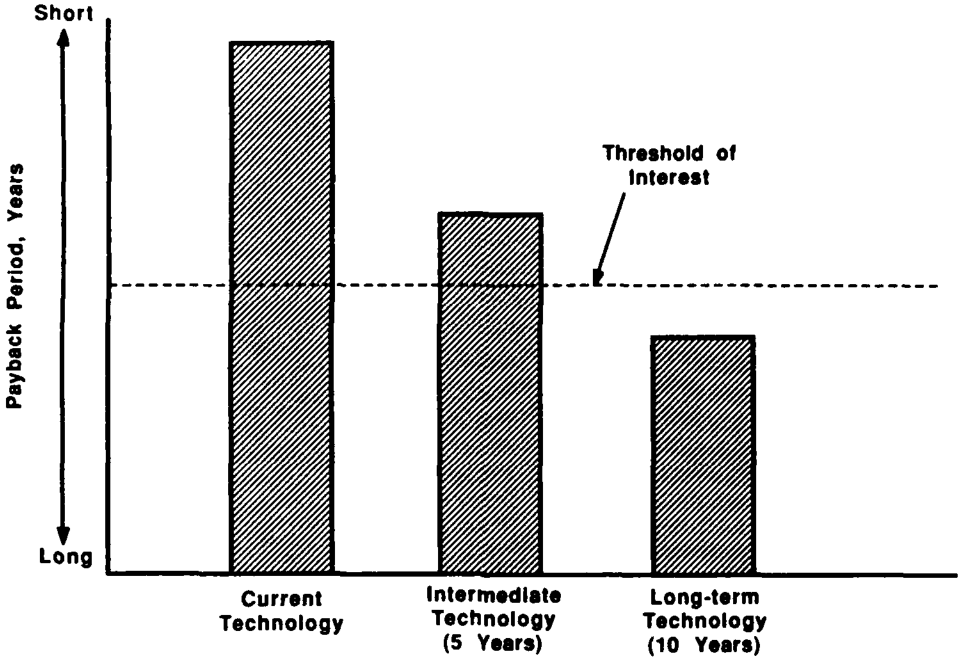

Figure 6. Economic performance impact on technology potential.

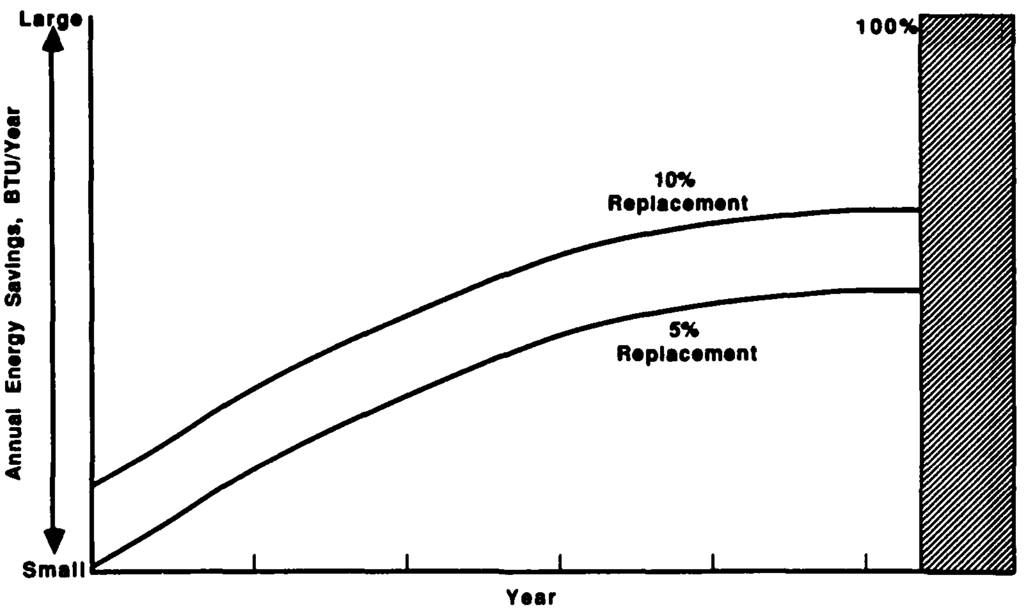

Figure 7. Impact of implementation rate on energy savings.

Step 3: Prepare Development Plan

The output of Step 2 is the basic information needed to prioritize technology developments based on criteria such as economic performance, impact potential, and risk factors. The development of a long-range development plan would include:

- Prioritize technology areas based on their potential relative to established criteria
- Develop strategies for introducing these technologies into the Army facility planning system. These strategies could include field demonstrations, technology adaptation, and laboratory experiments (for longer term technologies showing potential for major impacts)
- Develop schedules for implementing new technologies, taking into account their development status and ongoing R&D activities by industry and other Government agencies
- Estimate the budget requirements for the proposed developmental activities and assess the possibilities of securing outside support via cost-sharing and similar programs.

USACERL Criteria Set for Technology Selection

The mission thrusts and criteria currently used by USACERL to identify high-priority energy technologies for R&D are outlined in the Multiattribute Aid to Prioritization (MAPS) method (Figure 8). Based on a review of program plans, literature, and discussions with individuals at GRI, EPRI, and DOE, the following criteria appear to need additional emphasis at Army facilities:

- Energy savings/fuel switching system-wide potential
- Contributions to national policy
- Quantitative guidelines for economic performance
- Commercial status/development risks
- Project cost/benefit potential
- Army-specific modification or needs
- Technical/O&M support
- Timeliness of Army R&D effort
- Joint program potential.

The ranking criteria most appropriate for Army applications are highlighted in Table 2, which also shows the relationship of these criteria to the existing MAPS methodology. More detailed definition of these criteria, combined with the R&D program process outlined above, would facilitate and improve the energy technology selection

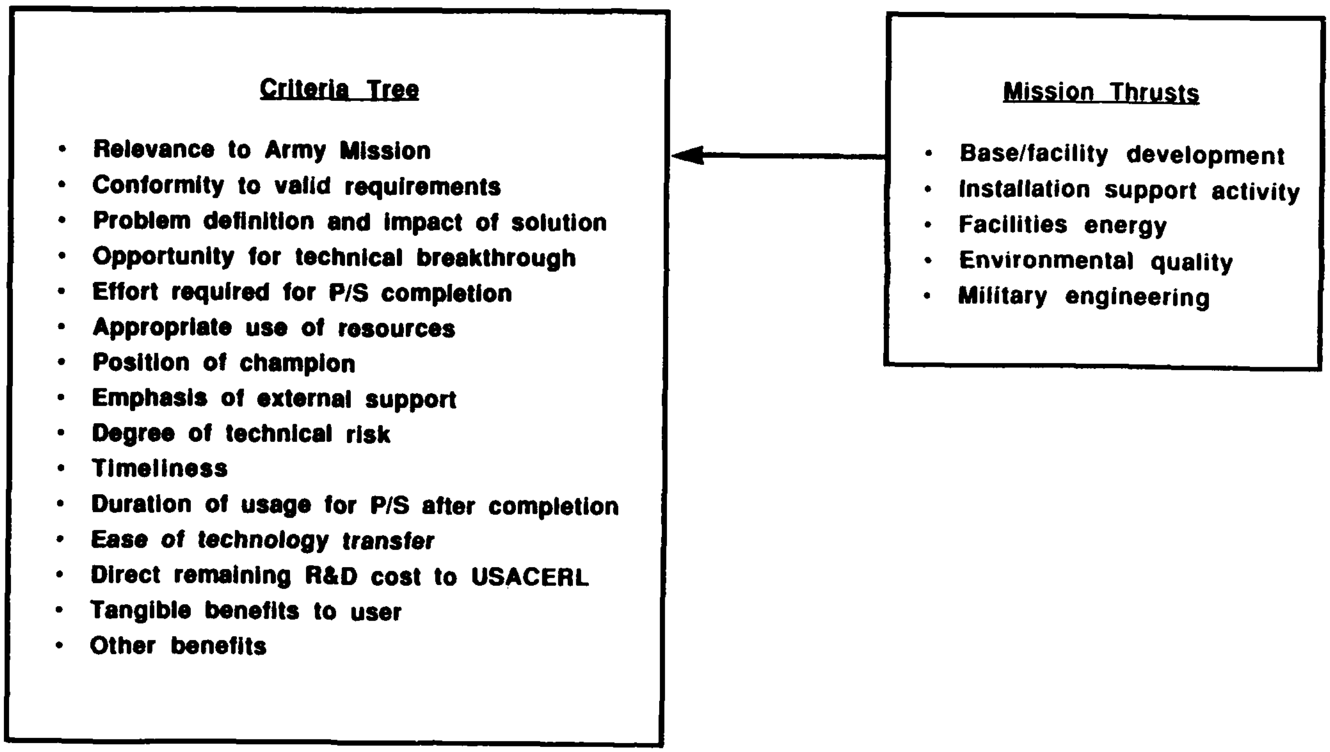

Figure 8. USACERL's current approach: the Multiattribute Aid to Prioritization System (MAPS).

Table 2

Ranking Criteria

Criteria	Relation to MAPS Process
ENERGY SAVINGS POTENTIAL (IMPACT)	- No criteria specifically address system-wide applicability and savings
- Number of Army applications - Energy use reduction - Demand charges - Timing of savings - Energy costs	- Factors AA (Relevance to Army Mission Areas), AB (Conformity to Requirements), and FA (Tangible Benefits) relate to this issue.
CONTRIBUTION TO NATIONAL POLICY	- No criteria explicitly addresses this consideration
- Coal use - Alternative energy sources - Environmental impacts - Balance of payments	- May be indirectly included in AB (Conformity to Requirements)
ECONOMIC PERFORMANCE	- No MAPS criterion specifies quantitative guidance
- Payback period - Near term - Mature technology	- Factor FA (Tangible Benefits) could, but not necessarily does, include such considerations
COMMERCIAL STATUS/ DEVELOPMENT RISKS	- Issues addressed directly by MAPS process:
- Corporate support - Technology status - Probability of success • Near term • Longer term	• AD (Opportunity for Tech. Breakthrough) • DA (Degree of Technical Risk) • BD (Technology Transfer)
PROJECT COST/BENEFIT POTENTIAL	- Issue incompletely addressed by MAPS
- Absolute costs - Cost/benefit ratio - Cost sharing potential - Intangible Benefits	- FA (Tangible Benefits) deals with environmental benefits - FB (Intangible Benefits) deals with environmental benefits

Table 2 (Cont'd)

Criteria	Relation to MAPS Process
ARMY-SPECIFIC MODIFICATION OR NEEDS	- Not addressed by MAPS per se
- Capacities - O&M procedures - Strategic impacts	- AD refers to special Army designs transferred to others
TECHNICAL O&M SUPPORT	- No criteria explicitly address this consideration
- Army skills available to support O&M of technology - Ease of operation and repair	
TIMELINESS OF ARMY R&D EFFORT	- Not specifically addressed by MAPS
- Impact on planning process - Timing of commercial availability - Need for Army-specific experience	- MAPS criteria that relate to issue include: • BA (Effort Required for PS Completion) • DC (Duration of Anticipated Usage)
JOINT FUNDING POTENTIAL	- Not currently addressed by MAPS process
- Increase range of project options within fixed budget - Improve USACERL's knowledge of equipment developments	

process for USACERL. The proposed criteria and their relationships to the MAPS process are discussed below.

Energy Savings/Fuel Switching Potential

The MAPS process has several criteria that indirectly address the issue of energy savings potential. However, the process does not specifically call for a quantitative estimate of energy use impacts, which complicates the task of comparing R&D options. Much of the information required for making such estimates is currently collected at Army facilities and summarized in documents such as *Facilities Engineering and Housing Annual Summary of Operations, Vol III, Installation Performance* (Annual Report). However, considerable data reduction and evaluation would be required to use this raw information in developing a broadly based strategy for prioritizing new technology options.

Contribution to National Policy

The MAPS process has no specific criteria that address national policy, although it may be implied under "Conformity to Requirements." Use of this factor may require compromises in other, more quantitatively based, criteria such as economic performance.

Economic Performance

The MAPS process does not provide quantitatively based guidance for economic performance. Some factors, such as "Tangible Benefits," might implicitly relate to this issue, but cannot be expected to be exercised consistently without guidance on how economic performance should be evaluated. Developing guidance on this key issue could contribute to a criteria set that can be applied consistently across divergent technology options.

Commercial Status/Development Risks

The existing MAPS process addresses risks in several ways. Application of this criterion requires that USACERL's R&D charter be well defined relative to such issues as the proportion of resources devoted to longer term, high-risk technologies as compared with short-term demonstrations of recently available, commercial technologies. In this regard, the MAPS criteria assume that USACERL does rather basic R&D, the results of which might be transferred to the civilian sector (e.g., MAPS criteria AD, Opportunity for Technical Breakthrough, and BD, Technology Transfer). Given USACERL's relatively limited resources compared with other organizations doing energy R&D, it appears unlikely that USACERL could perform the role of major high-risk R&D organization; instead, the laboratory is more likely to focus on smaller technology-gap R&D in specific areas.

Project Cost/Benefit Potential

Project cost/benefit potential are not formally addressed in the current MAPS process. One reason might be that such an assessment would require managers to estimate the potential financial benefits that might result if the technology is widely implemented (annual savings, etc.) and to compare these savings with the project cost. This process would involve considerable up-front analysis of the project for which a readily usable data base is often not available.

Army-Specific Modification

Some equipment available in the civilian sector may require modification for general Army use. Typical modifications are in standardization of parts, O&M procedures, and system capacity. Verifying the need for changes and overseeing their implementation could be a clearly defined role for USACERL. The current MAPS process does not address this issue.

Technical/O&M Support

O&M requirements for any new technology are of major concern to the operations staffs at Army facilities. New technologies have widely different O&M demands, with some increasing system complexity to effect energy savings (cogeneration) and others possibly reducing O&M needs by centralization or control strategies. The current MAPS criteria do not address this issue explicitly.

Timeliness of Army R&D Effort

A general objective of USACERL R&D activities would be to time them so that their results can contribute to the overall planning process and assist in the orderly implementation of new energy-related technologies. It is important that R&D be initiated early enough that results are available on a timely basis, but not so early that critical information necessary for a cost-effective program is not yet available. This issue, therefore, revolves around the question, "Is this the right time to initiate this project so that the Army is prepared to consider this technology when it becomes commercially available." This issue is not covered specifically by MAPS. Some of the MAPS criteria, however, do relate to this issue (e.g., factor BA, Effort Required for Completion).

Joint Funding Potential

Most new technologies that might be introduced into Army facilities will have been developed through programs supported in part by some combination of DOE, GRI, and EPRI. Army facilities often provide excellent sites for field-testing new technologies due to several factors, including:

- A potentially substantial market throughout Army facilities
- Controlled environment, leading to reduced legal/institutional problems
- Availability of personnel to obtain data and do routine checks.

Joint funding for equipment R&D and field experiments would provide a window for USACERL into equipment development and greatly increase the range of project options within fixed budget constraints. As such, one of the criteria for project evaluation should be the potential for joint funding with other supporting organizations or industry. This criterion is not included in MAPS.

Further Development of Criteria

The previous section has shown how the proposed set of criteria relates to the existing MAPS process. Based on this analysis, it appears that two areas in particular could benefit the current approach at USACERL: energy use/cost patterns and economic/impact analysis methods. These criteria could be incorporated as described below.

Energy Use/Cost Patterns

The Army collects some form of energy use data at all of its facilities. The level of detail varies widely from "at the gate" facility-wide data to more detailed information on end-use energy consumption. However, little effort is now expended to analyze this data or refine its level of detail to allow energy consumption patterns to be defined by end-use function on a large scale. The prioritization process should give emphasis to technologies that can have the greatest impact if implemented widely. In recognition of this benefit, other organizations with wide-ranging R&D portfolios give considerable attention to quantifying energy use patterns as applied to their planning needs.

The process of developing a detailed energy use pattern data base for the Army could be quite costly and time-consuming--particularly given the probable need to establish metering and audit programs to disaggregate the energy usage by end-use function. To avoid this expense, the process could be initiated as a relatively modest program by using parts of the data base as now collected. This data would allow managers to:

- Classify facilities by climate, size, and function, which might point to similar energy use patterns
- Review the existing energy use data base and segment by energy form (gas, oil, coal, electricity) and cost factors (e.g., electrical energy and demand cost segmentation) consistent with the detail allowed by the data base
- Estimate the probable end-use distribution of energy demand at typical facilities in each category using a knowledge of building inventories, functions, and climate as a guide
- Identify areas of major uncertainty in the breakdown of energy usage by major elements
- Consult at specific facilities to help verify the procedure for estimating energy use patterns
- Identify possible improvements in the current energy use reporting procedure that would facilitate the ability to develop system-wide energy use patterns consistent with the metering systems available now and in the near term
- Identify broad technology areas which the energy use/cost information indicates as having potential for major impacts if implemented widely.

Even with the deficiencies in the current energy use reporting procedure, the above process would provide a good first overview of energy use profiles to assist the technology selection process. The need for more refined data and analyses can be identified once the role of this information in the planning process is determined.

Economic/Impact Analyses Methodologies

As indicated earlier in this chapter, the MAPS process does not specifically include criteria to assess economic performance and impact potential. Undoubtedly, both factors are considered at some point in the deliberations. However, other organizations emphasize these criteria and attempt to impose a uniform approach to doing economic and market analyses so that input from different groups can be compared directly. Similarly, the MAPS process would benefit and become more quantitative if a procedure were developed which requires that the description of a technology option under consideration for project funding include:

1. Estimates of economic performance at different levels of the development process using a standard approach to economic performance analyses.

2. Estimates of potential impacts of using the technology based on realistic implementation rate assumptions (which are in turn influenced by the economic performance).

There are many approaches to economic analysis (e.g., payback period, return on investment, internal rate of return) and market assessment. It will, therefore, be important to develop a common methodology so that results from competing proposals are directly comparable. It is also critical that any such method be analytically straightforward (possibly computer-based) and can be used with a realistic amount of data (i.e., the information likely to be available). A too-complex or data-intensive methodology is unlikely to gain acceptance as a planning tool. USACERL could provide the base for implementing these selection criteria by developing a manual with supporting software to guide planners in assessing a technology's economic/impact potential. The process for developing this material would be to:

- Define a set of economic parameters for energy systems that would have high levels of implementation in Army facilities

- Create models for technology implementation in Army facilities, given the Army's specific decision-making process and budget considerations

- Prepare a manual for estimating economic performance of energy systems using agreed upon calculational approaches and economic parameters. The manual could be supplemented with a computer software package to facilitate the calculations

- Propose guidelines for estimating potential implementation rates in Army facilities based on economic performance and the end-use functions being addressed.

Procedural Issues

EPRI and GRI use various advisory panels consisting of senior representatives of their sponsors (e.g., electric or gas utilities) and outside expertise (e.g., academia, industry, etc) to help guide program development and provide diverse and highly knowledgeable input. Similarly, USACERL programs have input from their "clientele" through participation of senior personnel from Army facilities and USACE in exercising the MAPS. It is important that the extensive knowledge base of non-Army organizations be factored into USACERL's program planning process. USACERL is already making progress on this front by participating in Program Advisory Groups (PAGs) organized to provide advice on R&D being considered by GRI. This application provides USACERL with insight into the extensive R&D activities being undertaken by this organization which, in turn, can be factored into USACERL's program planning. Other options for increasing USACERL's exposure with other energy sector R&D organizations and advanced equipment suppliers could include:

- Participation in advisory groups dealing with technologies being developed through EPRI support

- Increased participation in (i.e., making presentations) and attendance at key conferences attended by major organizations engaged in energy systems R&D. Examples of two such meetings would be the annual Intersociety Energy Conservation Engineering Conference (IECEC) meeting (which tends to deal with advanced energy technology developments across a broad spectrum) and the annual conference/trade show sponsored by the American Society of Heating Refrigeration, and Air-Conditioning Engineers (ASHRAE), which provides exposure to the latest developments in HVAC, cogeneration, and building control systems

- Having guest speakers (possibly on a quarterly basis) from organizations such as GRI, EPRI, and industry trade groups make presentations to USACERL staff to widen USACERL's exposure to recent developments and to make these other organizations more aware of opportunities within the Army for advanced energy equipment technologies.

6 CONCLUSIONS AND RECOMMENDATIONS

USACERL has investigated the R&D planning approaches used by other organizations that have large-scale energy RDT&E programs. These approaches were analyzed for potential application to USACERL.

The current process used by USACERL in developing its plans draws on the experience of a wide range of Army personnel responsible for operating facilities and assessing technology developments. The MAPS process provides additional guidance to help them prioritize technology development options. The recommendations outlined below are primarily directed at supplementing the current process with quantitative information to facilitate the increasingly difficult task of prioritizing technologies with different cost and performance characteristics. Experience by other organizations facing similar problems in planning indicates that such information is essential to the technology selection process. It does not, however, reduce the need for good judgment based on a diversity of field needs and technological experience already built into the present USACERL process.

The two most important areas where additional quantitative information is required and should be added to the MAPS process are the definition of energy use patterns/cost (Step 1 of Figure 5) and the consistent estimation of technology economics and impact potential (Step 2). In addition, a specific requirement to assess the potential for joint RDT&E funding with other organizations should be added to both expand the scope of USACERL activities within its budget constraints and increase exposure to technology trends.

It is recommended that these criteria and methods be incorporated into USACERL's current annual planning process. The success of the resulting methodology will depend heavily on the willingness of professionals at USACERL to follow up on the recommendations and the efforts in disseminating the information to other Army staff involved in the decision-making process. Use of the methodology would at least help ensure that a consistent set of questions are asked to assess technology economic potential and impact on Army operations.

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